Open Access
J. Glob. Innov. Agric. Sci., 2023, 11(4):587-594
ISSN (Online): 2788-4546; ISSN (Print):2788-4538
DOI: https://doi.org/10.22194/JGIAS/23.1237
http://www.jgiass.com

Production approach model for oil palm (*Elaeis guineensis* Jacq) superior plant materials using artificial pollination studies

Yabani[1,3], Retna Astuti Kuswardani[1,3*], Agus Susanto[1] and Rahmad Syah[2,3]

[1]Department of Agricultural Science, Universitas Medan Area. Medan. Indonesia; [2]Faculty of Engineering, Universitas Medan Area. Medan. Indonesia; [3]Excellent Centre of Innovation and New Science, Universitas Medan Area; Kolam Gedung PBSI No.1 St. Medan. Indonesia
*Corresponding author's e-mail: retnaastuti@staff.uma.ac.id

The oil palm (*Elaeis guineensis* Jacq.) is an annual plant that yields vegetable oil and its derivatives. Seed plays a significant role in ensuring the long-term viability of commodities in order to achieve production progress. Knowing the compatibility or incompatibility between pistils and pollen by anticipating the development of the mesocarp and the pollination factor is one of the determining factors. By increasing oil yield, disease resistance, and other desirable traits, the proposed model seeks to increase the profitability and sustainability of oil palm cultivation. The mathematical model is intended to optimize production yields by obtaining superior oil palm (Elaeis guineensis Jacq) seeds through artificial pollination studies and by identifying the science of seed origin breeding, which is based on the availability of superior seeds from crossing female flowers of Dura trees with pollen from male flowers. The systematic and sustainable propagation of Pisifera trees Urgency The construction of the model included the selection of superior mother trees with the desired traits, data collection, artificial pollination processes, monitoring and evaluation of the fertilization process, seed germination and selection of the desired seeds, and field trials to confirm performance. Experimental pollination behavior was used to identify the value of the observation test with the variety, the common mean, the influence of the variety, the effect of the interaction of the variety, and the random value of the experimental data variable test by wrapping the female flower bunches with the Dura approach to produce Tenera.
Keywords: *Elaeis guineensis* Jacq, artificial pollination, optimization of production, palm oil, sustainability.

INTRODUCTION

The oil palm (*Elaeis guineensis* Jacq.) is a significant economic crop that is extensively cultivated in the tropics for its oil and several other derivative products used in industries (Bittencourt, *et al.*, 2022). The oil palm, which originated in Africa and arrived in Indonesia in 1848, was planted in the Bogor Botanical Gardens (Zahari, *et al.*, 2021; Mensah *et al.*, 2022). Seeds as plant materials play a significant role in agricultural development, particularly in Indonesian oil palm commodities. In 1911, when the first oil palm plantations in Indonesia were established, efforts were made to acquire seeds (Dassou *et al.*, 2022). This is accomplished through the mass selection of maternal trees, pollination among the selected trees, and the introduction of new germplasm. Pollination techniques are advancing, as are analyses of bunches and fruits, which are essential components (Suzanti, 2016). However, traditional breeding techniques cannot produce high-yielding plant material with desirable characteristics such as disease resistance, high oil yield, and cluster production (Seyum *et al.*, 2022). The development of palm oil production in the form of CPO illustrates how the level of Indonesian palm oil production has increased since 1980 The export value of oil palm plantations demonstrates that oil palm plantations are a significant contributor to Indonesia's national income and foreign exchange reserves. In 2017, total exports of oil palm plantations amounted to $31.8 billion, or 432.4 trillion Indonesian Rupiah (assuming 1 USD = 13,500 IDR) Indonesia has contributed 58% of the world's total CPO production, according to data released by the USDA in October 2020 (Ahmad *et al.*, 2022).

Palm oil, as a plant that generates palm oil and palm kernels, is one of the leading plantation crops that provides Indonesia with foreign exchange outside of oil and gas. The optimistic outlook for palm oil in the global vegetable oil trade has prompted the Indonesian government to encourage the expansion of oil palm plantations (Schouten *et al.*, 2023).

Yabani, R.A. Kuswardani, A.Susanto and R. Syah. 2023. Production approach model for oil palm (*Elaeis guineensis* Jacq) superior plant materials using artificial pollination studies. Journal of Global Innovations in Agricultural Sciences 11:587-594.
[Received 2 Nov 2023; Accepted 21 Dec 2023; Published 22 Dec 2023]

Through artificial pollination studies, this study proposes a paradigm for optimizing the production of superior plant materials for oil palm (Yousefi *et al.,* 2020; Swaray *et al.,* 2021). This model seeks to overcome the limitations of traditional breeding techniques in order to produce oil palm material with desirable traits that can improve the profitability and sustainability of oil palm cultivation (Low *et al.,* 2022; Suzanti *et al.,* 2016). The proposed model can produce populations of high-yielding oil palm materials by selecting superior mother trees based on the desired traits, collecting and storing pollen, carrying out artificial pollination processes, monitoring and evaluating the fertilization process, selecting the desired seeds, and conducting field tests. bigger with improved characteristics such as disease resistance, high oil yield, and cluster production (Lim *et al.,* 2021; Yusop *et al.,* 2022). This model offers a promising strategy for optimizing the production of high-yielding oil palm materials via artificial pollination studies and can contribute to the long-term viability and profitability of the palm oil industry (Myint *et al.*, 2019; Pertanian, 2020).
Therefore, optimizing oil palm productivity through artificial pollination research is a promising strategy for enhancing the profitability and viability of oil palm cultivation (Wahono *et al.,* 2022; John *et al.*, 2022).

MATERIALS AND METHODS

This research was conducted at the Seed Processing Unit (SPU), Production Division, Plant Materials Strategic Business Unit, Oil Palm Research Center (PPKS) Marihat Unit, Simalungun Regency-North Sumatra, with an altitude of 369 meters above sea level, at 02o55' North Latitude and 99o05' East Longitude. The research steps can be seen in Figure 1.

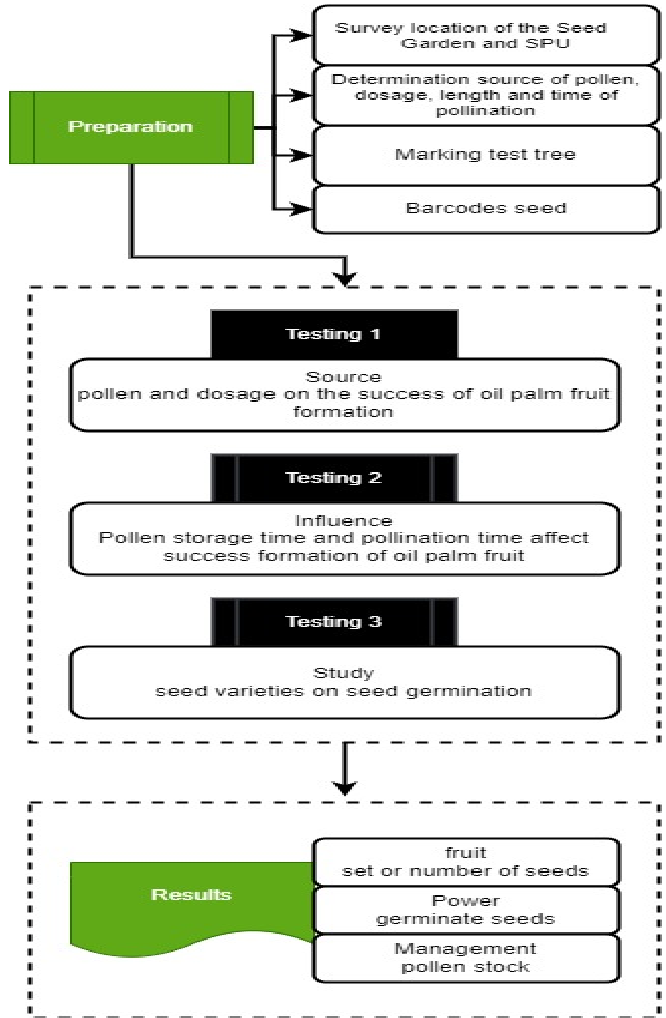

Figure 1. Research Methodology

Table 1. Seed Entered Oct 2019 - Sept 2020

Year	Seed	Area-1		Area-2		Area-1 and Area-2	
		Process Seeds		Process Seeds		Process Seeds	
		Good	Percentage	Good	Percentage	Good	Percentage
2020	Y1	3.233.447	65,43	1.313.902	62,94	4.547.349	64,69
	S1	7.815.133	67,12	1.869.711	77,43	9.684.844	68,89
	L1	1.493.548	65,85	290.085	70,86	1.783.633	66,61
	A1	102.661	44,93	157.313	70,80	259.974	57,69
	P1	4.225.579	77,17	2.060.886	86,45	6.286.465	79,99
	P2	263.196	64,73	-	-	263.196	64,73
	P3	511.418	66,80	32.369	75,77	543.787	67,28
	D1	481.745	66,83	2.151.929	78,16	2.633.674	75,81
	NG	60.862	-	1.006.583	80,35	1.067.445	78,90
	L2	27.234	37,70	-	-	27.234	37,70
TOTAL		18.214.823	68,42	8.882.778	76,80	27.097.601	70,96

Parameter Research Implementation and Observation

- **Field preparation**

Identify and document trees Observing the emergence of female floral clusters led to the selection of the broodstock as the research location.

- **Wrapping bunches of female flowers**

At least 10 days before the anthesis flower or the end of the sheath flowers (spatha) are still covered with 25% broken sheath condition, the flower bunches are wrapped by tightly enclosing all portions of the flower bunches from the tip of the bunch to the stalk of the bunch (stalk).

- **Pollination of female flower clusters**

When the flower experiences anthesis (at least 70% anthesis interest), pollination occurs. The majority of stigmas are now exposed and colored. This yellowish white is achieved by combining pollen and 4 grams of purified talc.

- **Unpacking**

Unwrap fifteen days after fertilization. The objective of the packaging is for the blossoms to grow naturally.

- **Harvesting**

When the clusters are 4.5 to 5 months old, they are harvested by cutting their stalks.

- **Parameter Observation**

Carried out by observing the bunch weight (kg), number of seeds (grains), seed weight (gr), seed diameter (mm) and the number of seeds suitable for seed (grains)

Use of Seed**:** Seed processing is the physical transformation of harvested seeds into clean, homogenous seeds according to predetermined standards. On oil palm the seed processing procedure begins with the extraction of seeds from fresh fruit clusters to obtain oil palm sprouts of high-quality (Ruiz-Alvarez *et al.*, 2021). The study used seedlings from 2020 to 2023; data are available in tables 1, 2, 3, and 4 (Ahmadi *et al.*, 2022).

PROBLEM SOLVING APPROACH

- **Testing 1**

The study used a randomized block design (RBD) with two factorials. The mathematical model for this research is Belt *et al.*, (2023).

$$Y_{ijk} = \mu + V_i + D_j + (VD)_{ij} + U_k + \varepsilon_{ijk}$$

Information:

Table 2. Seed Entered Oct 2020 - Sept 2021.

Year	Seed	Area-1 Process Seeds		Area-2 Process Seeds		Area-1 and Area-2 Process Seeds	
		Good	Percentage	Good	Percentage	Good	Percentage
2021	Y1	3.160.337	71,05	522.787	67,60	3.683.124	70,54
	S1	11.443.594	73,58	1.789.626	79,32	13.233.220	74,30
	L1	172.095	53,63	64.701	75,68	236.796	58,27
	A1	32.102	55,30	25.178	69,94	57.280	60,91
	P1	4.244.259	74,31	3.149.943	83,41	7.394.202	77,93
	P2	378.528	61,71	69.582	59,02	448.110	61,28
	P3	677.709	65,04	107.887	68,95	785.596	65,55
	D1	-	-	2.517.894	85,86	2.517.894	85,86
	NG	89.208	78,93	1.826.948	83,24	1.916.156	83,03
	L2	5.348	20,07	2.517	24,35	7.865	21,27
TOTAL		20.203.180	72,45	10.077.063	81,67	30.280.243	75,28

Table 3. Seed Entered Oct 2021 - Sept 2022.

Year	Seed	Area-1 Process Seeds		Area-2 Process Seeds		Area-1 and Area-2 Process Seeds	
		Good	Percentage	Good	Percentage	Good	Percentage
2022	Y1	4.068.472	70,90	769.555	71,06	4.838.027	70,92
	S1	11.354.909	77,91	1.829.501	81,79	13.184.410	78,43
	L1	762.730	69,15	325.799	74,41	1.088.529	70,65
	A1	343.919	56,25	43.831	51,96	387.750	55,73
	P1	3.135.161	76,88	4.303.181	88,48	7.438.342	83,19
	P2	713.619	73,15	-	-	713.619	73,15
	P3	1.004.672	73,57	-	-	1.004.672	73,57
	D1	6.623	84,58	2.466.984	84,73	2.473.607	84,73
	NG	655.046	77,05	589.841	71,86	1.244.887	74,50
	L2	18.430	61,40	-	-	18.430	61,40
TOTAL		22.063.581	75,22	10.328.692	83,04	32.392.273	77,55

Y_{ijk} : Observation values with pollen sources to- i and total pollen dose to- j
μ : Common mean
V_i : Effect of pollen source to - i
D_j : Effect of the number of doses of pollen to - j
$(VD)_{ij}$: The interaction effect of pollen source to- i and total pollen dose to-- j
U_k : Effect of repetition to - k ε_{ijk} = effect of experimental error

If the analysis of variance indicates that the treatment has a significant effect, the DMRT test is conducted at a 5% significance level.

- **Testing 2**

This investigation is a two-factor experiment. The first factor is the duration of time pollen (pollen) can be stored. The second factor is the time of pollination. This research's mathematical model is Fadda *et al*., (2022):

$$Y_{ijk} = \mu + \rho_i + \alpha_j + \beta_k + (\alpha\beta)_{jk} + \varepsilon_{ijk}$$

Information:

Y_{ijk} : The observed value of treatment to - j, and to - k and repeat to - i
μ : Common mean
ρ_i : Effect of repetition to - i
α_j : Effect of treatment to - j
β_k : Effect of treatment to - k
$(\alpha\beta)_{jk}$k: Effect of interaction treatment to -j and treatment to - k
ε_{ijk} : Effect of experimental error on treatment - j and to - k on repeat to – i

If the analysis of variance reveals that the treatment has a significant impact, the DMRT test at the 5% significance level is conducted.

- **Testing 3**

The mathematical model for this research is Daza, *et.al.* (2021):

$$Y_{ijk} = \mu + S_i + Y_j + (SY)_{ij} + U_k + \varepsilon_{ijk}$$

Information:

Y_{ijk} : Observational value with varieties to - i and varieties to - j
μ : Common mean
S_i : Effect of group varieties 540 to - i
Y_j : Influence of group variety taken to - j
$(SY)_{ij}$: The effect of the interaction of varieties to - i and varieties to - j
U_k : Effect of repetition to - k
ε_{ijk} : Effect of trial error

If the analysis of variance reveals that the treatment has a significant effect, then the DMRT test at the 5% significance level is conducted.

RESULT AND DISCUSSION

***Tesing 1. (Polen Sources and Dosage on Success of Formation Oil Palm Fruit (Elaeis Guineensis Jacq*.:** Oil palm trees are monoecious, which means that both male and female blossoms exist on the same plant. Male and female flowers mature at distinct times, thereby reducing the probability of self-pollination and promoting cross-pollination. To assure fruit formation, it is necessary to have a sufficient amount of pollen from the male flowers. The pollen source is oil palm trees that have been planted nearby. Maintaining a suitable ratio of male to female trees ensures that sufficient pollen is available during the flowering period of the female inflorescences (Yarra *et al*., 2019).

The efficacy of fruit formation can be affected by the amount and quality of pollen deposited on the stigma of the female flower. Pollen concentrations vary based on environmental factors and the cultivar of oil palm grown. In order to enhance the likelihood of successful fertilization and fruit set, a sufficient amount of live pollen is required. Too little pollen can lead to imperfect fertilization and decreased fruit formation, while too much pollen does not inherently increase fruit set and can lead to resource waste (Kamil *et al*., 2019). Pollen management entails harvesting pollen from male inflorescences, storing it under suitable conditions to preserve its viability, and applying it to female inflorescences using the proper techniques (Gorea *et al*., 2023).

Table 4. Water Production in 2018.

Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Amount
Rainfall	141	115	222	91	218	146	320	336	403	404	322	229	2.947
Rainy day	14	10	15	10	17	13	16	18	23	19	22	19	196
Too much water	21	-	97	-	69	26	200	216	283	284	202	109	1.507
Water deficit	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 5. Water Production in 2019.

Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Amount
Rainfall	222	258	380	345	364	172	191	199	73	395	171	180	2.950
Rainy day	15	16	20	18	20	13	6	10	14	17	17	15	181
Too much water	102	138	260	225	244	52	41	79	-	228	51	60	1.480
Water deficit	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 6. Water Production in 2020.

Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Amount
Rainfall	50	72	195	212	280	116	212	123	224	190	454	285	2.413
Rainy day	6	7	10	13	14	11	17	9	13	13	21	18	152
Too much water	-	-	-	-	149	-	88	-	77	70	334	165	883
Water deficit	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 7. Water Production in 2021.

Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Amount
Rainfall	241	56	357	141	411	273	321	348	251	347	514	206	3.465
Rainy day	15	6	14	13	21	15	12	20	12	14	23	10	175
Too much water	121	-	143	21	291	153	201	228	131	227	394	86	1.995
Water deficit	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 8. Water Production in 2022.

Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Amount
Rainfall	211	110	395	598	105	217	155	245	190	147	298	376	3.047
Rainy day	13	14	15	21	14	17	8	14	17	19	20	20	192
Too much water	91	-	265	478	-	82	5	125	70	27	178	256	1.577
Water deficit	-	-	-	-	-	-	-	-	-	-	-	-	-

***Pollination*:** Among the environmental factors that affect the efficacy of pollination are temperature, precipitation, and the presence or absence of flower-infecting pests and diseases. Several factors influence the production of fruit sets in oil palm plants, including the availability of water, nutrient content, and pollination quality. Palm oil production is determined by the sex ratio. Sex ratio is a comparison of the proportion of female flowers to total flowers (Adusei-Fosu *et al*., 2022).

The following are the results of rainfall, water production, excess water and water deficit from 2018-2022 which can be seen in the Table 5, 6, 7, 8, 9.

Overall, the results indicate effective water production for a balanced oil palm yield, which includes irrigation practices, rainwater harvesting, soil moisture management, and other water conservation measures. Sustainable water management practices not only contribute to higher oil palm yields, but also to their long-term viability. Can be seen in the Fig. 2.

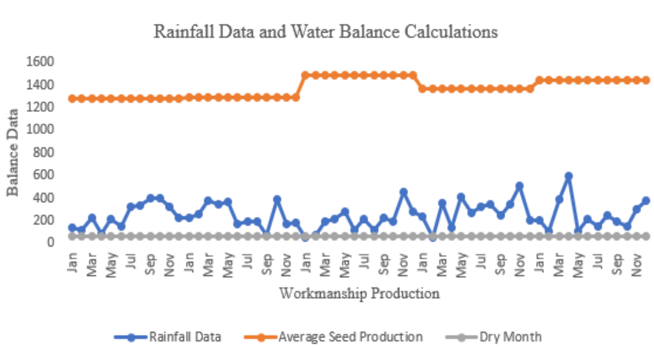

Figure 2. Water Production

Testing 2. (The Influence of Polen Storage Long Time and Polilation Time on Successful Establishment of Palm Oil Fruit (Elaeis Guineensis Jacq.): Pollen viability is essential for successful oil palm pollination and fertilization. Pollen storage time refers to the length of time pollen is stored prior to its application to female inflorescences. Pollen loses its viability and its ability to fertilize female blossoms as it ages. Pollen that has been recently collected typically has the maximum viability and is more likely to result in successful pollination. The optimal method is to use fresh pollen or to store it for a comparatively brief period of time under suitable conditions to preserve its viability. Pollen's expiration life is affected by factors such as temperature, humidity, and storage medium. Pollen is preserved for a limited amount of time by storing it in a cold, dry environment and on specialized storage media. Pollen viability can decrease with prolonged storage, resulting in diminished fruit formation (Suardi *et al.*, 2022).

Pollination Time: Pollination time influences the effectiveness of oil palm fruit formation. Oil palm flowers have a brief window during which they can be effectively pollinated. During this receptive period, pollination occurs for optimal fruit formation. Male and female flowers of the oil palm mature at distinct times; therefore, synchronization of the pollination process is crucial for successful fertilization. To ensure that viable pollen is available when female flowers are receptive, precise timing is required. Monitoring blossoming patterns in oil palm plantations is necessary for determining the optimal pollination time. Observing the developmental stages of the male and female flowers and coordinating the application of pollen during the receptive phase of the female flowers may be required. In addition,

environmental factors such as temperature and humidity can influence the timing of oil palm flowering. Understanding the specific blossoming patterns and climatic conditions of a specific region is therefore essential for efficient pollination management (Li *et al.*, 2022).

The materials used are bunches of female oil palm flowers, packing bags bunches (pollination bag), palm pollen, liquid insecticide, flour, cotton, alcohol, tire rubber, wire gauze, insulation and other supporting materials. This research consists of 2 experimental facts namely:

The first factor is the powder's shelf-life pollen:

$S0 = \leq 1\ year$

$S1 = \leq 2\ year$

$S2 = \leq 3\ year$

$S3 = \leq 4\ year$

$S4 = \geq 5\ year$

The second factor is the time of pollination:

$T0 =\ 07.00 - 08.00\ WIB$

$T1 =\ 08.00 - 09.00\ WIB$

$T2 =\ 09.00 - 10.00\ WIB$

$T3 =\ 10.00 - 11.00\ WIB$

$T4 =\ 11.00 - 12.00\ WIB$

From these two factors there were 25 treatment combinations, each treatment combination repeated 3 times, so there are 75 experimental units. The design used in this study was a randomized block design with parent trees as a group. Model mathematics for this research can be seen in equation 2.

Observations were made by harvesting the bunches ≥ 4.5 months after pollination and observed the ratio of normal fruit, parthenocarpy, to total fruit per bunch, number of spikelets in one bunch, bunch weight and stalk weight.

On the basis of the framework described above, the following results were achieved:

1. There are differences in the effect of pollen storage time on oil palm fruit formation.
2. The effect of different pollination times and the formation of oil palm fruit is different.
3. In the formation of oil palm fruit there is an interaction between the length of pollen storage and the difference in pollination time.

Testing 3 (Variety Study on Coconut Seed Germination Power Palm Oil): This research was conducted at the Seed Processing Unit (SPU), Production Division, Plant Materials Strategic Business Unit, Marihat Unit at the Palm Oil Research Centre (PPKS), Simalungun Regency, North Sumatra, with an altitude of 369 masl, at 02º55' North Latitude and 99º05' East Longitude.

At the Oil Palm Research Centre (PPKS) breaking of seed dormancy has been carried out routinely by heating at 38° – 40° C for 60 days it worked out fine. However, in line with the development of the palm oil business, there is a change in demand from consumers. high consumer demand results in no seed shelf life due to Seed consumers need sprouts in a short time, while processing germination takes a long time. so that a variety study was carried out on the germination power of oil palm seeds of each variety at each heating date.

The research on oil palm seed germination varieties was conducted with two factors and eight treatment combinations, each replicated three times, resulting in a total of twenty-four seed bunches serving as experimental material (Gintoron *et al.*, 2023; Setiawan *et al.*, 2023).

The experimental design can be explained as follows:

- **Factor**

Varieties of oil palm seed (considered a single factor with different levels representing distinct varieties) is the first factor. Repetition (number of times each treatment combination was repeated) is the second factor.

- **Combination Treatment**

The combination of these two parameters produced eight distinct treatment combinations.

- **Replication**

Each treatment combination was repeated three times, i.e., the experiment was conducted three times with the same factors and conditions.

- **Experiment Materials Entire**

With eight treatment combinations, each replicated three times, 24 seed bunches were utilized as experimental material.

This study involved germination trials for various varieties of oil palm, and the data acquired included germination rate, germination time, seedling vigor, and other pertinent measurements. The data were then analysed to determine the germination performance of the various oil palm seed varieties under the experimental conditions. The

Table 9. Coconut Seed Germination Results Palm Oil

Factor	Seed	Area-1 Process Seeds		Area-2 Process Seeds		Area-1 and Area-2 Process Seeds	
		Good	Percentage	Good	Percentage	Good	Percentage
First factor	S1	2.835.231	78,95	386.325	83,38	3.221.556	79,46
	P1	958.402	77,40	1.335.424	88,81	2.293.826	83,66
Second factor	Y1	1.667.430	68,52	203.663	74,43	1.871.093	69,12
	P2	241.472	76,63	-	-	241.472	76,63
	P3	257.876	67,25	-	-	257.876	67,25
	D1	-	-	525.605	69,90	525.605	69,90
TOTAL		6.168.931	74,13	2.517.154	81,53	8.686.085	76,13

mathematical model for this research can be seen in equation 3. Results can be seen in the Table 9.

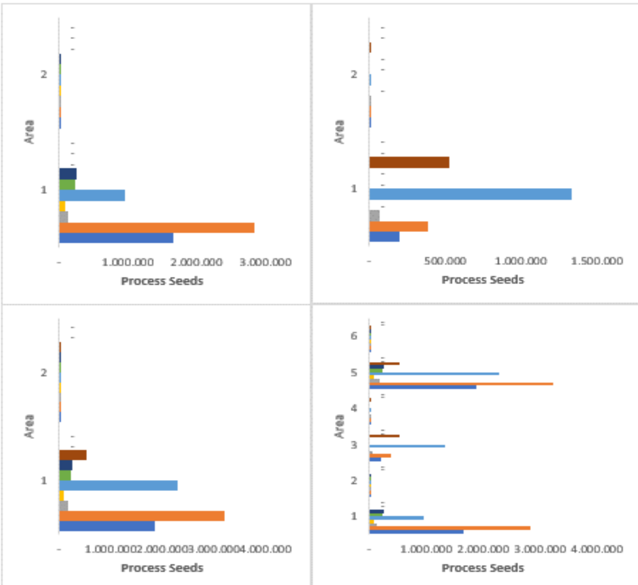

Figure 3. Germination Optimization Results for Each Area

Conclusion**:** By utilizing the dura method for cultivating tenera, producers can cultivate seeds with a high oil content and optimal yield potential. Tenera seeds are in great demand in the palm oil industry due to their superior yields and oil quality compared to other varieties. Optimization was carried out by carrying out three stages of research, namely Polen Source and Dosage on the Success of Oil Palm Fruit Formation, Effect of Pollen Storage Time and Pollution Time on the Success of Oil Palm Fruit Formation (Elaeis Guineensis Jacq), and Study of Oil Palm Seed Germination Varieties. through good agricultural practices and sustainable management strategies. Oil palm plantations can be made more productive and profitable by continuously monitoring and adapting to changing environmental conditions.

Acknowledgement**:** Authors Thanks to DRTPM PDD Grant. 027/LL1/AL.04.03/2023, 1852/LP2M/03.8.1/VII/2023 and Excellent Centre of Innovations and New Science-PUIN-UMA.

Authors' contributions**:** Yabani: Writing, Investigation, analysis of result., R.A Kuswardani: Orginal draft preparation, conceptualization, A. Susanto: Supervision project, validation., R Syah: Data Curation, Validation, Methodology.

Funding**:** DRTPM PDD Grant. 027/LL1/AL.04.03/2023, 1852/LP2M/03.8.1/VII/2023.

Availability of data and material**:** The data used in this study has been appropriately described in the manuscript.

Funding**:** This research received no external funding.

Institutional Review Board Statement**:** Not applicable.

Informed Consent Statement**:** The authors are fully aware and satisfied with the contents of the article.

Data Availability Statement**:** The data used in this study has been appropriately described in the manuscript.

Conflicts of Interest**:** The authors declare that they have no conflict of interest.

REFERENCES

Bittencourt, CB., T.L.C.D. Silva, J.C.R. Neto, L.R. Vieira, A.P. Leão, J.A.A. Ribeiro and M. T. Souza. 2022. Insights from a Multi-Omics Integration (MOI) Study in Oil Palm (Elaeis guineensis Jacq.) Response to Abiotic Stresses: Part One-Salinity. Plants 11:1755.

Zahari, Z., R.A. Kuswardani, Y. Lubis. 2021. Kajian Strategi Integrasi Nilai-Nilai Keberlanjutan Kedalam Proses Pembangunan Kelapa Sawit Rakyat Di Tapanuli Selatan. Journal Agrica 14:33-47.

Mensah, P., H. Danso, S.J. Mitchual and M.B. Donkoh. 2022. Effect of Moisture Content and Preservatives on the Discoloration of Oil Palm (Elaeis guineensis Jacq.) Lumber. Forests 13:1799.

Dassou, O.S., X. Bonneau, H. Aholoukpè, W. Vanhove, J. Ollivier, S. Peprah, A. Flori, T. Durand-Gasselin, A.G. Mensah, B.A. Sinsin and P. Van Damme. 2022. Oil palm (Elaeis guineensis Jacq.) genetic differences in mineral nutrition: potassium and magnesium effects on morphological characteristics of four oil palm progenies in Nigeria (West Africa). OILSEEDS AND FATS CROPS AND LIPIDS 10:29:31.

Suzanti F. 2016. Diversity of Vascular and Insects Canopy Epiphytes on Palm Oil in North Sumatra, Indonesia. American Journal of Environmental Protection 5:39.

Seyum, E.G., N.H. Bille, W.G. Abtew, P. Rastas, D. Arifianto, H. Domonhédo, B. Cochard, F. Jacob, V. Riou, V. Pomies and D. Lopez. 2022. Genome properties of key oil palm (Elaeis guineensis Jacq.) breeding populations. Journal of Applied Genetics 63:633-50.

Ahmad Hamidi, H.N., N. Khalid, Z.A. Karim and M.R.K. Zainuddin. 2022. Technical Efficiency and Export Potential of the World Palm Oil Market. Agriculture 12:1918.

Schouten, G., R. Padfield and D. Kraamwinkel. 2023. Contested representations: A comparative analysis of palm oil sustainability in Malaysian and Dutch media. World Development Sustainability 3:100075.

Yousefi, M., A.S.M. Rafie, S.A Aziz, S. Azrad, A.B.D. Razak and A. binti. 2020. Introduction of current pollination techniques and factors affecting pollination effectiveness

by Elaeidobius kamerunicus in oil palm plantations on regional and global scale: A review. South African Journal of Botany 132:171-9.

Swaray, S., M.Y. Rafii, M. D. Amiruddin, M.F. Ismail, S. Jamian, M. Jalloh, Y. Oladosu, M.M. Mustakim, M. Marjuni, O.K. Kolapo and S.C. Chukwu. 2021. Assessment of Oil Palm Pollinating Weevil (Elaeidobius kamerunicus) Population Density in Biparental dura × pisifera Hybrids on Deep Peat-Soil in Perak State, Malaysia. Insects 12:221.

Low, E.T.L., N. Azizi, M.A.A. Halim, N.S.N.M. Sanusi, K.L. Chan, N. Amiruddin, N. Jayanthi, M. Ong-Abdullah , R. Singh, R. Sambanthamurthi, M.A. Manaf . 2020. Oil Palm Genome: Strategies and Applications. The Oil Palm Genome. pp. 83-115.

Suzanti F., R.A. Kuswardani, S. Rahayu and A. Susanto. 2016. Contribution Of Epiphytes On The Canopy Insect Population In Oil Palm Plantations In North Sumatera. ARPN Journal of Engineering and Applied Sciences 11:6982-98.

Lim, C.H., S. Lim, B.S. How, W.P.Q. Ng, S.L. Ngan, W.D. Leong and H.L. Lam. 2021. A review of industry 4.0 revolution potential in a sustainable and renewable palm oil industry: HAZOP approach. Renewable and Sustainable Energy Reviews 135:110223.

Yusop M.R., J. Sukaimi, M.D. Amiruddin, M. Jalloh, S. Swaray, O. Yusuff and S.C. Chukwu. Genetic Improvement of Oil Palm Through Recurrent Selection. The oil palm genome. pp. 35-46.

Myint, K.A., M.D. Amiruddin, M.Y. Rafii, M.Y.A. Samad, S.I. Ramlee, Z. Yaakub and Y. Oladosu. 2019. Genetic diversity and selection criteria of MPOB-Senegal oil palm (Elaeis guineensis Jacq.) germplasm by quantitative traits. Industrial Crops and Products 139:111558.

Pertanian, K. 2020. Laporan Tahunan. 2019. Direktorat Jendral Perkebunan Kementerian Pertanian Republik Indonesia-Perkembangan Perkebunan. *Direktorat Jendral Perkebunan: Jakarta*.

Wahono, D.R., B.D. Tampubolon, A.B. Mulyono, F. Isharyadi and W.C. Anggundari. 2022. Application of superior palm oil seeds based on SNI 8211:2015 to increase productivity significantly. In AIP Conference Proceedings. AIP Publishing 2664:040010.

John, M. J.J., R. Yarra, L. Wei and H. Cao. 2022. Oil Palm Breeding in the Modern Era: Challenges and Opportunities. Plants 11:1395.

Ruiz-Alvarez, E., E.S. Daza, K. Caballero-Blanco and M. Mosquera-Montoya. 2021. Complementing assisted pollination with artificial pollination in oil palm crops planted with interspecific hybrids O × G (Elaeis guineensis × Elaeis oleifera): Is it profitable?. OCL 28:27-27.

Ahmadi, S.A. and A. Peivandizadeh. 2022. Sustainable Portfolio Optimization Model Using PROMETHEE Ranking: A Case Study of Palm Oil Buyer Companies. Discrete Dynamics in Nature and Society.pp. 1-11.

Belt, D., A. Grygier, A. Siger, D. Kmiecik, S. Spasibionek and M. Rudzińska. 2023. Changes in Oil Quality and Peroxidase Activity during Germination of Rape Seeds and Mustard Seeds. Applied Sciences 13:2196.

Fadda, A., D. Sanna, E.H. Sakar, S. Gharby, M. Mulas, S. Medda, N.S. Yesilcubuk, A.C. Karaca, C.K. Gozukirmizi, M. Lucarini and G. Lombardi-Boccia. 2022. Innovative and Sustainable Technologies to Enhance the Oxidative Stability of Vegetable Oils.Sustainability 14:849.

Daza, E., I. Ayala-Díaz, R. Ruiz-Romero and H.M. Romero. 2021. Effect of the application of plant hormones on the formation of parthenocarpic fruits and oil production in oil palm interspecific hybrids. Plant Production Science 24:354-62.

Yarra, R., L. Jin, Z. Zhao and H. Cao. 2019. Progress in Tissue Culture and Genetic Transformation of Oil Palm: An Overview. International Journal of Molecular Sciences 20:5353.

Kamil, M., K. Ramadan, A.G. Olabi, C. Ghenai, A. Inayat and M.H. Rajab. 2019. Desert Palm Date Seeds as a Biodiesel Feedstock: Extraction, Characterization, and Engine Testing. Energies (Basel) 12:3147.

Gorea, E.A., E.T. Tokilala, O.D. Esiegbuya, A.A. Azeez, C.S. Siang and E.H. Jaber. 2023. Oil palm tree diseases. In: Forest Microbiology 339-73.

Adusei-Fosu, K., M. Dickinson, J. Unnikrishnan, G. Scott, M. Osei-Wusu and C. Somchit. 2022. A Biosecurity Tool: High-Intensity, Pulsed Polychromatic Light and UV-C Treatments of Oil Palm Pollen and Spores of Fusarium oxysporum f. sp. elaeidis. PhytoFrontiers 2:347-51.

Suardi, T.F., L. Sulistyowati, T.I. Noor and I. Setiawan. 2022. Analysis of the Sustainability Level of Smallholder Oil Palm Agribusiness in Labuhanbatu Regency, North Sumatra. Agriculture 12:1469.

Li, K., I. Grass, T.Y. Fung, R. Fardiansah, M. Rohlfs, D. Buchori and T. Tscharntke. 2022. Adjacent forest moderates insect pollination of oil palm. Agriculture Ecosystems and Environment 338: 108108.

Gintoron, C.S., M.A. Mohammed, S.N. Sazali, E.Q. Deka, K.H. Ong, I.H. Shamsi and P.J. King. 2023. Factors Affecting Pollination and Pollinators in Oil Palm Plantations: A Review with an Emphasis on the Elaeidobius kamerunicus Weevil (Coleoptera: Curculionidae). Insects 14:454.

Setiawan, R., D.D. Pandu, C.T. Zetira and S.D. Azahra. 2023. Legal Protection for Consumers at the Medan Oil Palm Research Center (PPKS). Formosa Journal of Multidisciplinary Research 2:1119-30.